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WASTE TO ENERGY TECHNOLOGY IMPLEMENTATION IN PAKISTAN

Case Lahore

Technology and Communication
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I would like to start with praising and thanking Allah (SWT) for giving me the strength and ability to do my thesis, without whom this would not be possible. I would also like to immensely thank my supervisor, Adebayo Agbejule, for his continuous assistance throughout my thesis work. Likewise, I express my gratitude to Mr. Muhammad Rafiq Khan, for helping me with my thesis. Lastly, I would like to greatly thank my best friend, my close friends and foremost my family for supporting me throughout this process.

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TIIVISTELMÄ

Tekijä	Sajal Maqsood
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Tämän opinnäytetyön tavoitteena oli tutkia Pakistanin jäteongelmia ja luoda puitteet jäteratkaisujen käytännölliselle toteuttamiselle Lahoressa ja valita sopiva jäte-energiateknologia.

Tapaustutkimusmenetelmää käytettiin tässä opinnäytetyössä, ja tiedonkeruu tehtiin haastattelemalla 3 avainhenkilöä, joilla on asiantuntemusta Lahoren jätehuolto-ongelmista.

Tutkimuksen tulokset osoittavat, että keskeiset esteet, jotka estävät soveltuvan jätehuoltojärjestelmän toteuttamista Lahoressa, ovat jätteiden kosteuspitoisuus, kaatomaksut ja jätelainsäädäntö. Lisäksi tutkimuksessa todettiin, että WOIMA-jäteteknologia soveltuu Lahoren ympäristöön.

Käytännöllisestä näkökulmasta tämä opinnäytetyö voi toimia ohjeena jäteteknologian toteuttamiseksi Pakistanissa ja mahdollisesti muissa kehitysmaissa.

Avainsanat jätehuoltojärjestelmä, jäteenergiateknologia, toteutus

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ABSTRACT

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The objective of this thesis was to study waste problems in Pakistan and create a framework for practically implementing waste solutions in Lahore and to select a suitable waste to energy technology.

A case study research method was used, and the data collection was done by interviewing three key individuals with expertise in waste management problems in Lahore.

The findings of the study show that the key barriers hindering implementation of a suitable waste management system in Lahore are the moisture content of the waste, tipping fees and the waste legislations. In addition, the study found that the WOIMA waste technology is suitable for Lahore's environment.

From a practical point of view, this thesis can act as a guidebook for implementing a waste-to-energy plant in Pakistan and perhaps other developing countries.

Keywords	Waste management, waste to energy technology and implementation

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1 INTRODUCTION

The increasing population and development of civilization has led to a tremendous increase in waste. This unattended waste creates high environmental and health risks. The disposal and management of waste are a global challenge. This problem hinders the sustainable development, economic growth, and social inclusion of the future. Especially in developing countries, the mismanagement of waste is a predominant issue. Engineered solution for waste disposal in developing countries are restricted due to negative economic legislations, negative political will, technical limitations and operational limitations. /12/

The main solutions for waste in developing countries are open disposal, open burning, and waste picking. Open disposal causes heavy metal pollution within the surrounding environment, makes the place visually unattractive, creates air contamination through spread of odors and GHG gases, spreads diseases and pollutes surface and ground water. Open burning causes the emission of harmful pollutants (COx, NOx). Waste picking causes serious health risks for the pickers. /12/

In common with other developing countries, Pakistan also faces serious challenges in terms of MSW management. The continuous increase of waste in the absence of proper waste management poses enormous challenges for public health, environmental protection, and sustainable development in Pakistan. /19/

In Pakistan, approximately only 60% of solid waste is collected, resulting in uncollected rubbish gathering in the streets. Pakistan's largest city, Karachi, with a population of over 20 million has more than 14,000 tonnes of solid waste being produced daily. Waste management is ineffective, including shortage of trained manpower, lack of reliable data and poor administration. Solid waste collection is primarily governed by municipalities and waste is collected door to door for a fee of between \$0.71 - \$19 USD per household each month by private waste pickers. Recyclable materials such as metal and plastic are segregated by homeowners and/or waste pickers and sold for revenue. Non-recyclable waste is typically transported to large containers designated by the town municipal administration, and subsequently moved to landfills. Unauthorized dumping at other sites is reported to occur throughout Karachi./19/

1.1 Research Problem

The literature shows that waste management is not properly managed in Lahore; there is no controlled or even semi-controlled waste disposal facility. Waste collection and transportation is the main focus; however, the collection coverage is only about 68%. It is estimated that currently around 27% of waste by weight is being recycled through the informal sector. Despite the volume of waste generated in Lahore, there is little information on waste to energy generation possibilities. Inclusivity of users and providers of the waste management system is low in the city, as not all stakeholders are consulted in the decision-making processes. Waste management costs US$20 per tonne of waste, where the main focus is only on waste collection, and the current user fees are much lower than the actual costs./17/

These problems create the need to study the waste management system in Lahore and determine the key issues to be addressed in converting waste to energy and selecting the appropriate waste to energy technology.

1.2 Research Question

Based on the problems discussed above the following research questions will be addressed in the study:

1. What are the key factors (barriers) in developing a suitable waste management system in Pakistan?

2. What is the suitability of the WOIMA technology in Pakistan?

1.3 Research Methodology

Research is either quantitative research or qualitative. This thesis is a qualitative research (case study) which is focused on the *outcome* of the process (WtE implementation in Lahore). Qualitative research is a scientific method of observation to gather non-numerical data, while focusing on meaning-making. /29/

Case Study is a strategy for doing research which involves an empirical (based on observation or experience) investigation of a particular contemporary phenomenon within its real-life context using multiple sources of evidence. /30/

A case study can have one or several cases. The aim of a case study is to identify, analyze and find solutions to the case/cases. In a case study, questions can be made in the event that the research object is a phenomenon at present. Suitable method to collect the materials for the case study much be selected. Interviews and written materials are commonly used. /15/

Case study can be categorized as a mapping research. Mapping research is to analyze the information at hand, look for new views/phenomenon, clarify poorly known facts and develop hypothesis. This thesis is a single case study, meaning it focuses only on one case. It produces new information and is a critical study that has not been made earlier in the selected context. /15/

Mapping Research Methods focuses on showing how the following four key features of a research project are linked to one another within the philosophy of science: research aims, research strategies, data collection and data analysis /31/.

There are two types of data collected for a case study. Primary data which is directly collected information by the researcher. Secondary data is information/materials collected by someone else. It is possible to get answers for some parts of the research problem from existing material (secondary data), however for some parts the information has to be collected by oneself (primary data). /15/

There are four categories of interviews. Structured interviews have specifically formed questions, which are given to each interviewee. Open interviews have more of open-ended questions or discussions are done around a theme which varies for each interviewee. In the semi-structured interviews same questions are given to all the interviewees, however they can answer as they like, or there can be discussions. In theme interviews themes are formed around which discussion takes place with varying information from each interviewee./15/

In this thesis, structured interviews were conducted for primary data collection, with characteristics of semi-structured interviews as well, where the interviewees were also free to answer as they liked. It happened naturally in the interviews, and thus discussions took place. This broadened the views around the study. The interviews were carried out, wherever it was most convenient for the interviewees. Also, the researcher had limited time in the country where the interviews were conducted.

Analysing data means to create meaning and value through compacting the fragmented sections of information gathered throughout the research process. There are no set rules on the analysis method of data. Commonly, in qualitative research data is collected in phases or side by side with different methods. Thus, analysis is done throughout the collection of data. /15/

In this thesis, the analysing has been done along the way, with the bulk analysis done at the end stage of the thesis. The collection of data has been mostly done all at once after the questions were carefully prepared through the theoretical framework.

In this thesis, interviews of different companies were conducted related to the case study and the usage of several different sources (own + interviewees) gave depth to this thesis. The advanced prepared questionnaire made the collection of data relatively easy. The interviews were conducted in English or Urdu, whatever the participants were most comfortable in, this led to more open discussions. The interviews were both recorded and noted down.

It is important to follow certain measurements or research methods for the value that have been added to the thesis to be reliable and valid. Reliability means that the results of a measurement are repeatable, which means the research is able to give non-random results. Validity means the ability of research method to measure what it was supposed to measure. /15/

2 LITERATURE REVIEW

2.1 Waste in General and Type of Waste

The EU Waste Framework Directive (WFD) (EC, 2008) defines waste as ‘‘any substance or object which the holder discards or intends or is required to discard”. /32/

Solid Waste refers to any solid material or object which the holder discards or intends or is required to discard. Below are some examples of solid waste.

Municipal Solid Waste (MSW) is waste coming from households and generally includes plastics, textiles, paper, biodegradable waste (food), metals, glass, wood, rubber, and leather. MSW sources may vary from country to country due to different legal frameworks and lifestyles. Some countries may include also commercial waste, hospital waste, construction and demolition waste within MSW. /1/

According to the Official Journal of European Union, municipal waste does not include waste from production, agriculture, forestry, fishing, septic tanks and sewage network and treatment, including sewage sludge, end-of-life vehicles or construction and demolition waste. In the current study, we adopt the definition of MSW in the United Nations Environmental Program Report. /1/

Commercial waste is waste produced as a result of activities in stores, restaurants, markets, offices, hotels, motels, print shops, service stations, auto repair shops and other commercial activities. It may include materials such as consumer electronics, batteries, tires, white goods, paper, cardboard, metal, plastics, food waste, wood, and glass. /10/

Hospital waste is a special type of waste that is generated in smaller quantities but is very infectious and harmful waste for humans and the environment if not dealt with properly. Hospital waste is made up of risky waste and non-risky waste. Risky waste includes infectious waste, pathological waste, sharps, pharmaceutical waste, genotoxic waste, chemical waste and radioactive waste. Non-risky waste includes all general waste. /8/

Construction and demolition waste is solid waste produced by the construction industry. It may include materials such as concrete, wood, metals, plastics, soils, and glass. /10/

Electronic waste is discarded electrical and electronic equipment and components that have been discarded by its owner as waste without the intent of re-use. It includes a wide range of products, almost any household or business item with circuitry or electrical components with power or battery supply.

Liquid Waste includes those wastes that can be eliminated through sewer networks or are lost to ground water. Liquid waste can be classified as wastewater or sewage that are generated from toilets, baths, laundry places, lavatories, and kitchen- sinks. /10, 11/

Hazardous waste are those wastes which have high risk of causing environmental harm and thus they require strict environmental control when disposing of /10/. Hazardous waste can be found within solid and liquid wastes.

This thesis is focusing on solid waste.

2.2 Waste to Energy (WtE) Conversion Technologies

Waste to energy (WtE) conversion technologies are a variety of treatment technologies that convert the waste into energy, such as electricity, heat, fuel, or other usable end-products. There are numerous WtE conversion technologies, which are divided based on their energy conversion processes into Thermal, Thermo-chemical, Bio-chemical, Thermal, and mechanical and Chemical WtE technologies. /1, 3/

2.2.1 Thermal WtE Technologies

Incineration is the complete combustion of waste from which heat is recovered to produce steam, which then through turning on steam turbines produces energy in the form of electricity or heat or both. The waste is burned at a temperature between 750ºC and 1100ºC in the presence of oxygen (aerobically) /1, 2/.

There are many different types of incineration technologies (Figure 1), which either use non-treated and inhomogeneous waste or pretreated and homogenized waste. The main technologies are explained below.

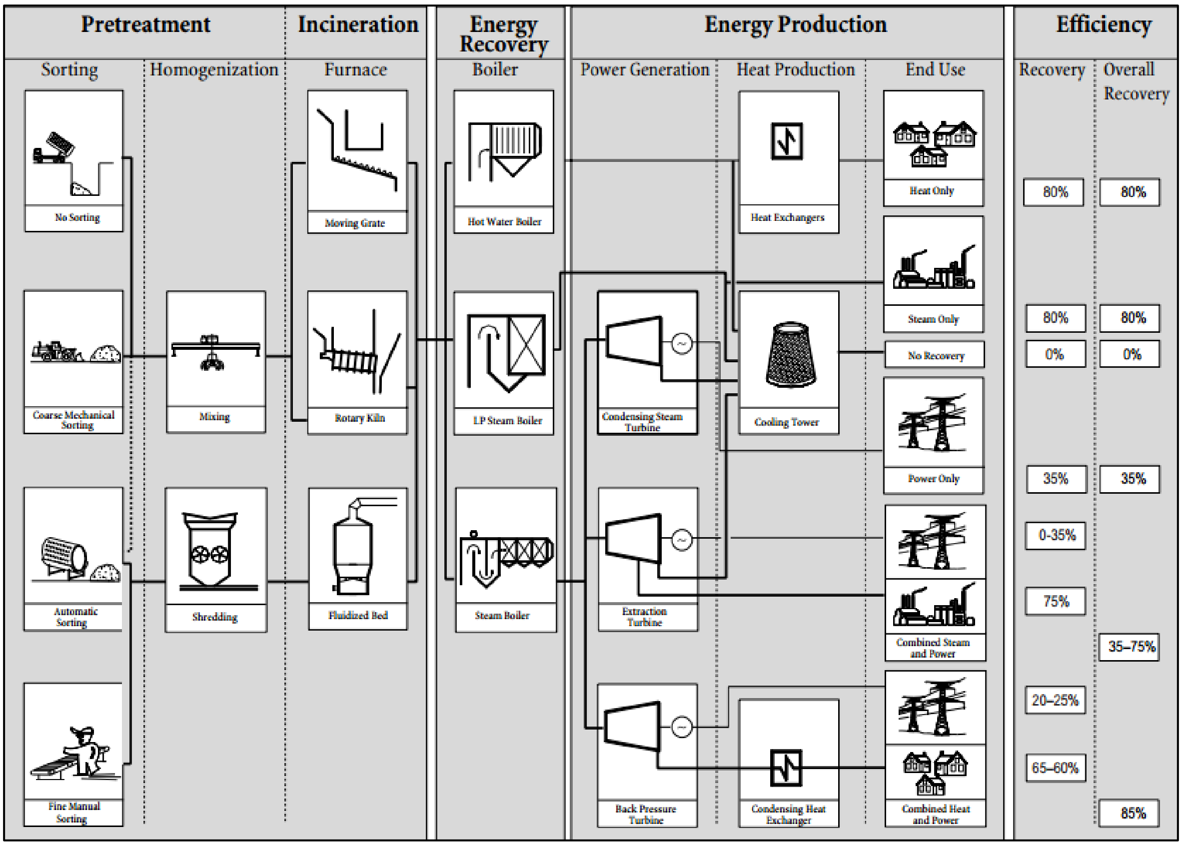

Figure 1. Incineration Methods /13/

Moving grate incineration

In this technology, waste in dried and then burned at high temperature on a layered moving grate with air supply (combustion air) coming from beneath the grate. The grate technology mixes well the waste and distributes the combustion air properly. There are various types of grates: forward moving, backwards moving, double moving, rocking, and rolling. The advantages and disadvantages of this method are listed in Table 1 below. /13/

Table 1. Advantages and disadvantages of moving grate incineration

Advantages	Disadvantages
No need for pre-sorting or shredding of waste	Capital and maintenance costs are high
Widely used technology	
Suitable for variety of wastes	
Up to 85% thermal efficiency	
Waste capacity of furnace up to 1200 tons/day	

Rotary kiln incineration

This technology uses a rotating combustion chamber to burn waste. The waste keeps moving within the chamber allowing the waste to vaporize. The advantages and disadvantages of this method are listed in Table 2 below. /13/

Table 2. Advantages and disadvantages of Rotary Kiln incineration

Advantages	Disadvantages
No need for pre-sorting or shredding of waste	Not commonly used technology
Suitable for variety of wastes	High capital and maintenance costs
Up to 80% thermal efficiency	Limited waste input (480 tons/day/furnace)

Fluidized bed incineration

This technology uses a furnace/vessel with a bed of granular material, such as silica sand, limestone, or a ceramic material. This material is heated through air blowing from the bottom of the furnace. Waste is placed onto the heated material to be incinerated. The advantages and disadvantages of this method are listed in Table 3 below. /13/

Table 3. Advantages and disadvantages of Fluidized Bed Incineration

Advantages	Disadvantages
Low capital and maintenance cost due to its simple design	Relatively new technology
Up to 90% thermal efficiency	Strict pretreatment of waste
Suitable for liquid and solid waste separate or combined, wide range of fuels, combined fuels	

2.2.2 Thermo-Chemical WtE technologies

Pyrolysis is the process of breaking down waste at temperatures between 300ºC and 1300ºC in the absence of oxygen (anaerobic), which produces liquid fuel for generation of heat energy or feedstock. /1, 4/

Gasification is the process of partially oxidizing (burning) waste at an elevated temperature ranging between 500ºC and 1800ºC to produce synthetic gas, which can be used to generate electricity or heat or both. /1, 4/

Torrefaction is the process of slowly heating waste (biomass) at a temperature between 200ºC and 300ºC in an inert atmosphere. This is done to upgrade the waste into a more energy dense product called torrefied pellets (TOPs) or briquettes. TOPs are a substitute product for coal or charcoal, which are used for domestic heating, biomass co-firing and gasification. /4/

Plasma Technology is the process of heating waste (low-energy biomass) at a high temperature until it reaches and creates plasma, which is high-energy synthetic gas. To startup this process, energy is required, which can be wither thermal or electric current or electromagnetic radiations. /4/

Hydrothermal Liquefaction is a process in which waste (wet biomass) is converted into bio-oil that is used as fuel for electricity or heat generation. This technology does not require dry waste (feedstock) to produce energy, thus drying is not necessarily unlike in other processes. Hydrothermal liquefaction is good when using high moisture content waste such as organic residues and sludges /7, 23/.

2.2.3 Bio-chemical WtE Technologies

Composting is the process of biologically breaking down (organic) waste in the presence of oxygen to produce compost. Compost can be used to improve soil conditions, prevent erosion, be a carbon storage within soil, used in the process of reclaiming land and used as a final cover for landfills. /1, 4/

Bioethanol fermentation is the process by which waste is converted to bioethanol (biofuel) by alcohol-fermenting microorganisms. Bioethanol is used as fuel for engines to generate electricity. /4/

Anaerobic digestion is the process of biologically breaking down (readily degradable) waste by microorganisms in anaerobic conditions. It creates biogas (mixture of methane and carbon dioxide) which can be used as a fuel, as well as, digestate, which can be used as soil conditioner or refuse-derived fuel. /1, 4/

Landfilling with gas recovery (see Figure 2 below): in this process, the gas (biogas) emitted from landfill waste is captured and collected into a power plant, which then creates electricity and or heat. The waste undergoes biological and chemical break-down at the landfill and produces landfill gas (LFG), which is rich in methane for energy use. /5, 6/

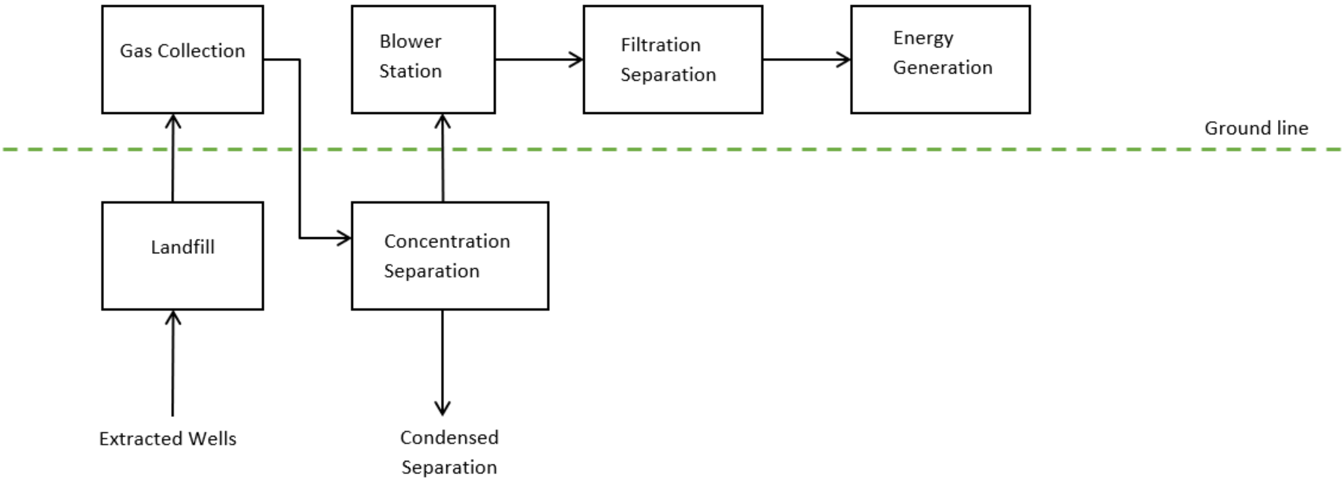

Figure 2. Landfilling with gas recovery

2.2.4 Mechanical and Thermal WtE Technologies

This type of technology combines mechanical and thermal processes to create energy, in the case of producing refuse derived fuel (RDF). MSW goes through pulverization and drying which creates solid fuel. This solid fuel goes through combustion to produce thermal energy (heat). /1/

2.2.5 Chemical WtE Technologies

Esterification / Transesterification is the process of converting fats and oils in waste (biomass) into ester and glycerol by reacting them with alcohol in the presence of catalyst. Ester (fatty acid methyl ester) is then used as a biofuel and the by-product glycerol has also commercial value. /21/

2.3 Drivers of WtE

There are various reasons for why WtE technologies are being created, developed into better technologies, and perhaps also being avoided. Requirements to create a WtE project within a location and other aspects of WtE integration with be discussed in this section. This thesis is focusing on the drivers of the incineration technology.

2.3.1 Causes for an increase in the need for WtE

Space restrictions: there is not enough land to dump the increasing amount of waste; WtE technologies can reduce waste volume and mass by up to 75 to 90 percent. Thus, WtE solves the problem for the demand of landfills. /13/

Energy generation: the need for energy and especially renewable energy is increasing with time. There is much energy value within waste that can be utilized, and it meets the need for renewable energy. /13/

Climate Change: much efforts is put to decrease the harms of climate change. WtE reduces greenhouse gas emissions and helps countries to meet their climate goals by removing waste from landfills, reducing open burning and replacing fossil fuels. /13/

Health and Environment: In developing countries, waste is mostly discarded in open dumpsites, streets and within rivers (water bodies), which creates a polluted environment and consequently health problems for the public. WtE technologies tackle these problems enormously. /13/

2.3.2 Challenges of implementing a WtE plant

There are many different challenges in implementing a waste to energy plant. The main recognized challenges are described below.

Waste Characteristics: The type of waste is of utmost importance when it comes to creating a WtE plant, it can lead to a successful or a failure of a project. The energy efficiency of WtE is directly related to the waste characteristics. Each region/area has certain waste composition and quantity of waste. This quantity of waste may vary with different seasons and natural disasters. /1/

In developing countries, there is often an issue of the waste having high moisture content within the organic waste. This means the waste has a low calorific value and thus does not have enough energy to create a WtE plant. Furthermore, there is an issue of inert materials existing within MSW, such as construction and demolition waste that are not very efficient for a WtE plant. The poor quality and quantity of waste can be a major hindrance in the implementation of an WtE plant. /1/

Costs: On average the cost of an incineration plant is much higher than other waste technologies. Investment cost and the operational cost are the two major costs that are needed in order to develop a thermal WtE plant. If there are problems within these, the project can collapse. /1/

Investment costs are all costs related to project planning and development. These include cost of, siting, feasibility studies, permitting, consultation, design, land, equipment, and construction. /1/

Operation costs are all costs needed to keep the plant working. These include cost of labour, fuel, energy, maintenance and repair, emissions control and monitoring, revenue collection, public communication, management and administration, safe disposal of residues, accident response and decommissioning. The estimated total cost of an incineration plant can be seen below in Figure 3. /1/

Developing countries are making basic low-cost plants due to the high investment costs, which may lead to breakdown risks and more pollution in the end. In developed countries, these costs are much higher due to higher workforce costs, architecture, and stricter emission standards. The cost of equipment for the plant are overall same globally, however the cost of engineering, construction, land, and labouring varies in each country. /1/

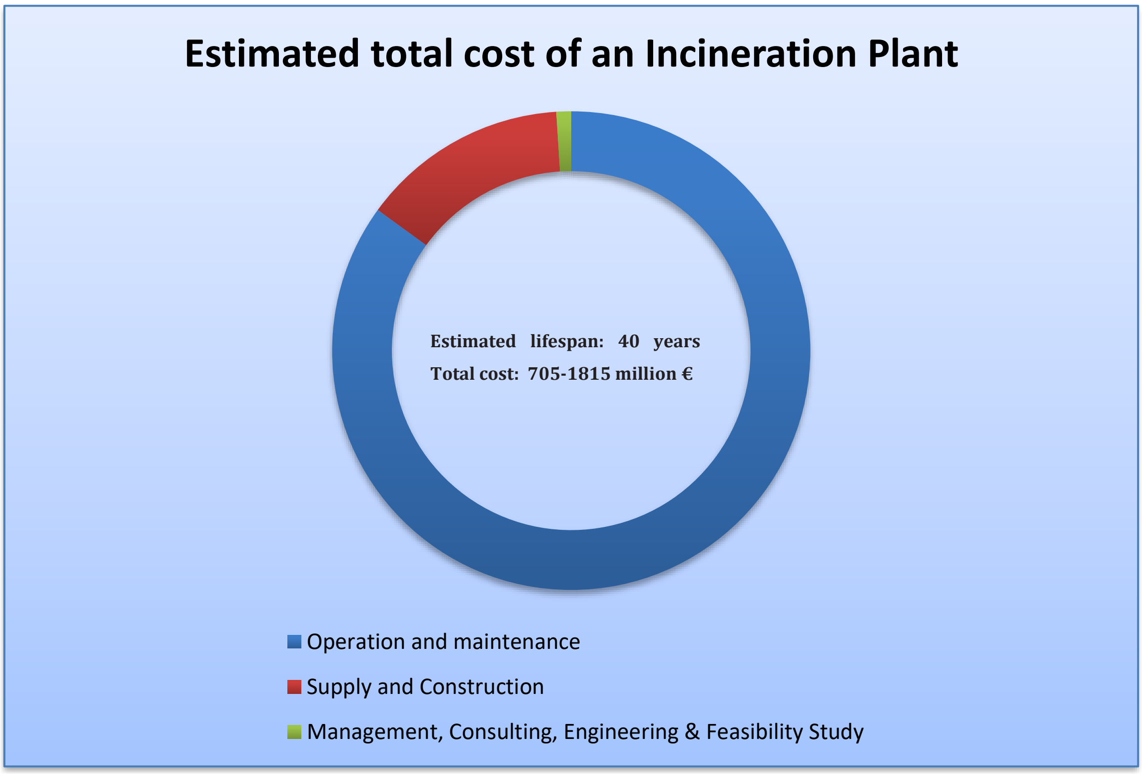

Figure 3. Estimated cost of incineration plant /1/

Legal: The legal aspects for an incineration plant vary from country to country and so there are different legal obstacles to tackle for each WtE project. They are heavily correlated with the people, environmental situation, and economics of the country. /1/

Environmental: (before the 20th century) Globally, waste incinerators are one of the leading sources of air pollution, which have been recently improved with better operation of combustion and plants being equipped with flue gas cleaning systems. Developing countries are opening up to having more incineration technologies developed. However, the poor maintenance and operation of incinerators in developing countries is leading to more emissions. On the other hand, the European Union is moving away from incinerators to other WtE technologies, due to having very stringent emission laws. /1/

Social: Public resistance against thermal WtE projects can be a major problem. It is a necessity to acquire public approval for starting an incineration plant. There are three main reasons to why there is disapproval from the public (see Table 4 below). Generally, incinerators have a negative view on the world due to causing environmental pollution and health problems. /1/

Table 4. Reasons for Public opposition

Public Opposition	Description	Causes	Solutions
Site Allocation	Plant not located in the right place	Not in my back-yard phenomenon	Key criteria to be followed when choosing sites for incinerators that follow the European Union standards
Lock – in effect	The act of dedicated investment into the plant and the need of fixed amount of waste is required for plant lifecycle	Rubbish running out Loss of waste prevention programs Municipalities have to provide fixed amount of waste or else pay fines Plant overcapacity	Importing waste from neighbouring countries Overview future waste production amounts Create sustainable waste management systems

Table 4. Reasons for Public opposition

Public Opposition	Description	Causes	Solutions
Trade-offs of the 3R's (reduce, reuse, recycle)	Incineration plants require minimum amount of waste for operation.	Prevents the 3R's as most of the waste used for incineration is recyclable Decreases the livelihood of formal recyclers	Prioritization of 3R's when creating a WtE solution Create legislation to ban incineration of recyclable and compostable waste Introduction of waste fee for waste to be incinerated/landfilled

2.3.3 Integrating a WtE Technology within a Location

There are many factors to consider when integrating WtE technology within a location. These factors are preliminary conditions, technology fit, implementational conditions and stakeholder analysis. The stages are described below. /1/

Waste characteristics Identification: Knowing the waste characteristics is the first important step in the integration of a WtE technology. The collection of necessary waste data and waste analysis should be done. The incineration implementational requirements should be met according to the waste data (Table 5). Waste characteristics identification include the following things. /1/

1. Waste assessment survey of the city/municipality:

- Waste data collection such as waste composition, calorific value, waste quantity, collection coverage, recycling rate and landfill disposal rate
- Future waste quantity data: population of the city/municipality, intercity and transboundary waste flow, waste created from tourism industry, waste created from natural disasters
- Imported waste: if there is a need for imported waste then the waste survey of those areas should be done as well.

2. Waste management performance analysis:

- This analysis is done using waste assessment survey as a benchmark indicator
- Waste management assessment tool: this tool combines quantitative indicators for waste generation and composition, as well as qualitative composite indicators
- Analysis of waste collection, treatment, disposal, the 3R's and governance aspects

Table 5. Incineration plant implementation requirements

Waste Characteristics	Waste Management Level
MSW should be sorted	Systematic waste collection and transportation exist
Minimum waste calorific value of 7 MJ/kg	MSW is disposed in well-controlled landfills
MSW quantity should be over 100,000 tons/year	A collection fee system exists, and citizens pay for it
	A comprehensive legal framework addressing WtE is available

Waste Characteristics	Waste Management Level
	Implementation of waste prevention measures
	High recycling and composting/anaerobic rates

Technology Fit: infrastructure of the city/municipality and the technical requirement conditions should be looked at.

1. Infrastructural requirements:

- Availability of a closed landfill close to the incineration plant, where flue gas residue can be disposed off
- Availability in the market and disposal options of WtE plant residue
- An appropriate and efficient waste collection and transportation system within the city. For waste transportation to the plant
- Identification of type/s of energy to be generated and its demand and accessibility for end users
- The local capacity of the city/ municipality, for monitoring emissions

2. Assessment of potential WtE technologies:

Experts should be consulted to assess which technology would suit the best for the city according to the waste management performance and local environment

3. Efficient use/minimization of incinerators and final disposal:

Strategies should be developed that maximize the reuse, recycling and composting of waste that will be used for incineration plant. For example, waste sorting facilities to extract recyclables before incineration and usage of residues of the plant for road construction and reclamation material.

Implementational Conditions: all the necessary conditions should be laid out to setup the WtE plant.

1. Life Cycle Assessment: Impacts and benefits of the plant throughout its lifecycle should be assessed.

2. Emissions Assessment: all direct emissions, indirect emission and GHG emissions should be considered. The amount and toxicity level of flue gas and waste residues should be thoroughly examined.

3. Financial Model: long-term funding needs should be secured for a WtE project. Initial investment costs can be obtained through:

- Direct revenues: gate fee, waste fee on citizens, sale of energy produced
- Indirect revenues: increasing tipping fee at landfills, regularizing open waste dumping
- Government subsidies
- International funds
- Private sector investment
- Public-private partnership (PPP)
- Foreign currency accessibility

Stakeholder Identification (Figure 4): the acceptance of a WtE project by the stakeholders is very important to implement the plant. A thorough stakeholder analysis should be carried out, so that strategies (steps) can be initiated accordingly. As opposition is expected when implementing such a project, due to its negative view of potential health and environmental impacts, it is important to have good communication with the public. Communication with stakeholders and the public can be done through open consultation and dialogues. The public should be kept informed of the planning progress of the project, as well as be encouraged to support the policies related. /1/

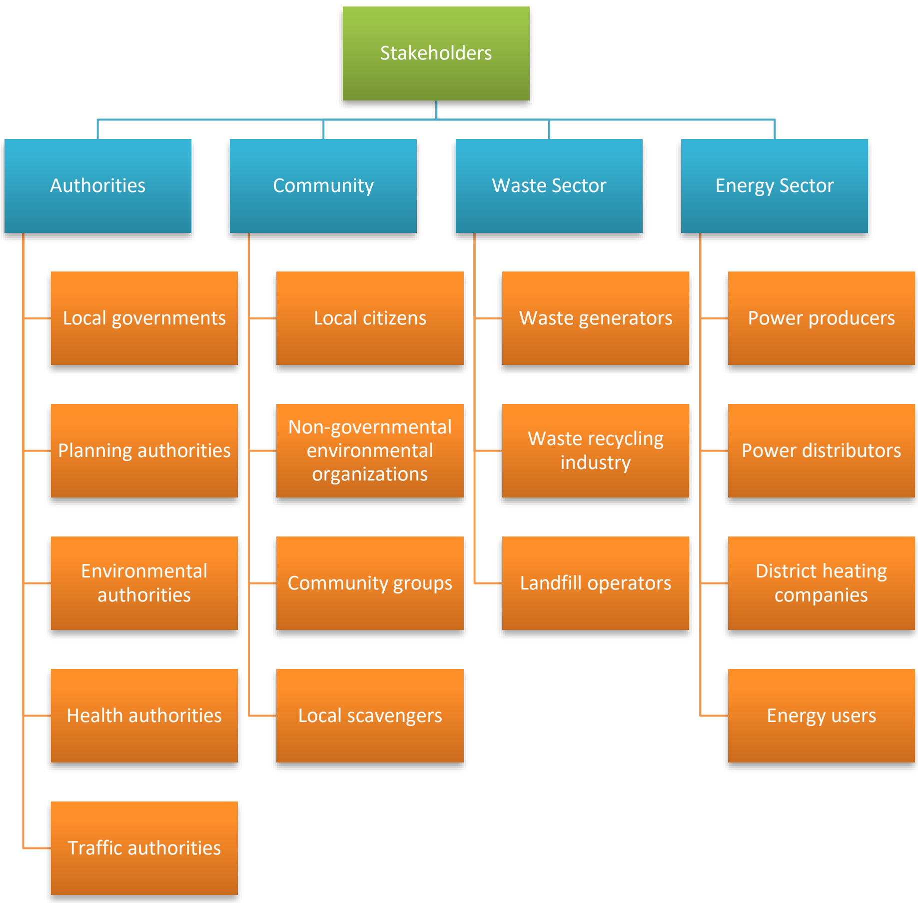

Figure 4. Stakeholder Identification

In summary, there are various stages in the process of implementing a WtE plant. The key stages are preliminary conditions, technological fit, implementational conditions and stakeholder analysis (Figure 5).

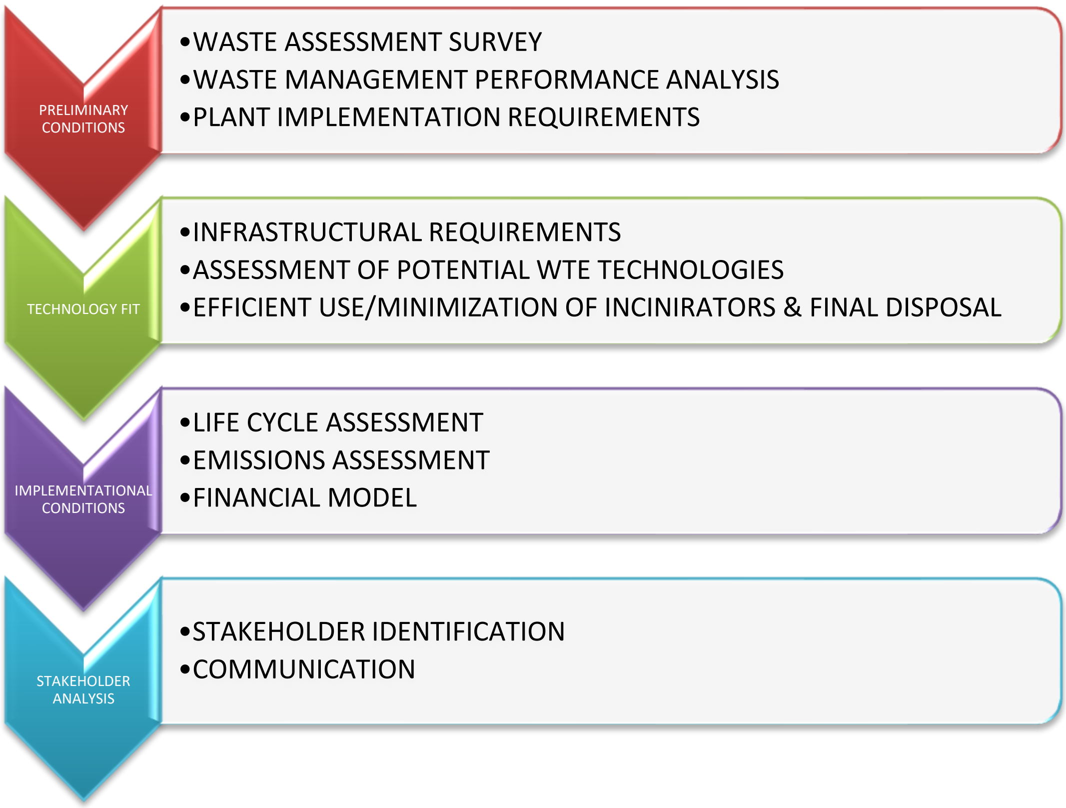

Figure 5. Stages of implementing WtE technology

2.4 Checklist of Decision Making

There are many decisions to consider when implementing a WtE plant. The checklist below is intended for planning whether a WtE technology should be built or not. /1/.

Waste data and characteristics

…Does the waste quality and quantity meet thermal WtE requirements?
…Do seasonal waste variations and transboundary waste flow affect future waste projections?
…Is the MSW sorted at the source in the environs of the city or municipality, for both households and commerce?
…What percentage of the waste sent for disposal is recyclable or compostable?
…Are source recyclables and organics collected separately and sent to recycling and composting facilities?

Infrastructure

…Does systematic waste collection and transportation exist?
…Is a controlled landfill available for safe disposal of thermal WtE residues?

Environmental aspects

…Do emission standards for thermal WtE follow international standards?
…Are compensatory strategies available to mitigate environmental impacts?
…Is there installed capacity to regularly monitor emissions, including for persistent organic pollutants?
…What are the occupational health risks for workers and how can they be mitigated in everyday operations and in case of serious accidents?

Economic aspects

…Is the energy produced accessible to local users and/or available for sale in the market?
…Is there an available market for thermal WtE residues?
…Have long-term financial sources been secured?
…Is there access to foreign currency?

Legal aspects

…Does a comprehensive legal framework exist for all planned WtE technologies?
…Is there a decommission plan or decommission regulations in place for the thermal WtE plant?

Social aspects

…Can the working conditions of informal recyclers be improved?
…Are compensatory strategies available to mitigate social impacts?
…Are all relevant stakeholders being considered and consulted?

Risk assessment

…What are the flooding and tsunami risks, and what would the environmental and health impacts be if the plant was flooded?
…What is the hurricane or cyclone risk, and what environmental and health impacts would result if the plant was damaged by a hurricane or cyclone?
…What is the seismic risk, and what environmental and health impacts would result if the plant was damaged by an earthquake?
…What is the elevation of the site, and what environmental and health impacts would result if the site was affected by rising sea levels?

Alternatives

…Are there alternative WtE technologies that better suit the local conditions?
…Is thermal WtE, including biogenic CO2 emissions, a good option in the local context according to the life cycle assessment?
…Is there a way to improve rates of recycling and composting?
…Are there waste prevention policies in place?

2.5 WOIMA Technology – the Modular Waste to Energy Power Plant

The WOIMA technology (Figure 6) is a thermo-chemical WtE technology and uses the pyrolysis process with moving grate incineration method to burn the waste. The waste is dried and then burned at high temperature anaerobically (pyrolysis) on a layered moving grate with air supply coming from beneath the grate. The char combusts and moves to the bottom ash compartment/cooling pool, which is transported to ash processing unit through conveyor belts. /24/

Figure 6. Woima modular WtE power plant

The incinerated waste then is burnt in a chamber with adiabatic conditions. From the radiation channel, waste heat is collected in the recovery boiler. The steam generated is converted into superheated saturated steam for the steam genset in the membrane walls of the radiation channel. The air is cleaned from pollutants (emission control system). The saturated and superheated steam is fed to a steam turbinegenerator set, and the heat and pressure are transformed through a rotating turbine into electricity./24/

It is a modular plant meaning the units of the power plant can be easily transported. The plant comes with secure enclosers, installation platforms with technical solutions and protective housing on site./24/

- The power plant design is based on standard 20’ and 40’ container-sized modules.
- The WOIMA plant uses 150-200 tons of solid waste per day (30,000 – 200,000 tons/year)
- Its incineration capacity is 5-7 tons per hour
- 30-year lifespan
- 1-4 incineration lines can be built
- 2.7 MW of electricity/line
- Produces 200 m^3 of drinking water/day if provided with suitable raw sources
- Fuel calorific value of 7 – 16 MJ/kg
- Can take waste moisture content of up to 55%
- Different auxiliary systems can be added to the plant
- Less than one hectares of land is needed

Types of waste the WOIMA plant can process:

1. Municipal solid waste (MSW)
2. Refined waste fuels (RDF, REF, SRF)
3. Industrial, commercial, and institutional waste
4. Construction and demolition waste
5. Agricultural waste
6. Different biomasses (empty fruit bunch(EFB), rice husk)

Apart from waste to energy solutions, Woima offers pre-sorting solutions (Figure 7), waste collection and reception expertise, and waste-to-value solutions. Depending on the needs of a country, Woima can provide an ecosystem of various solutions, technologies put together to acquire the maximum value. /24/

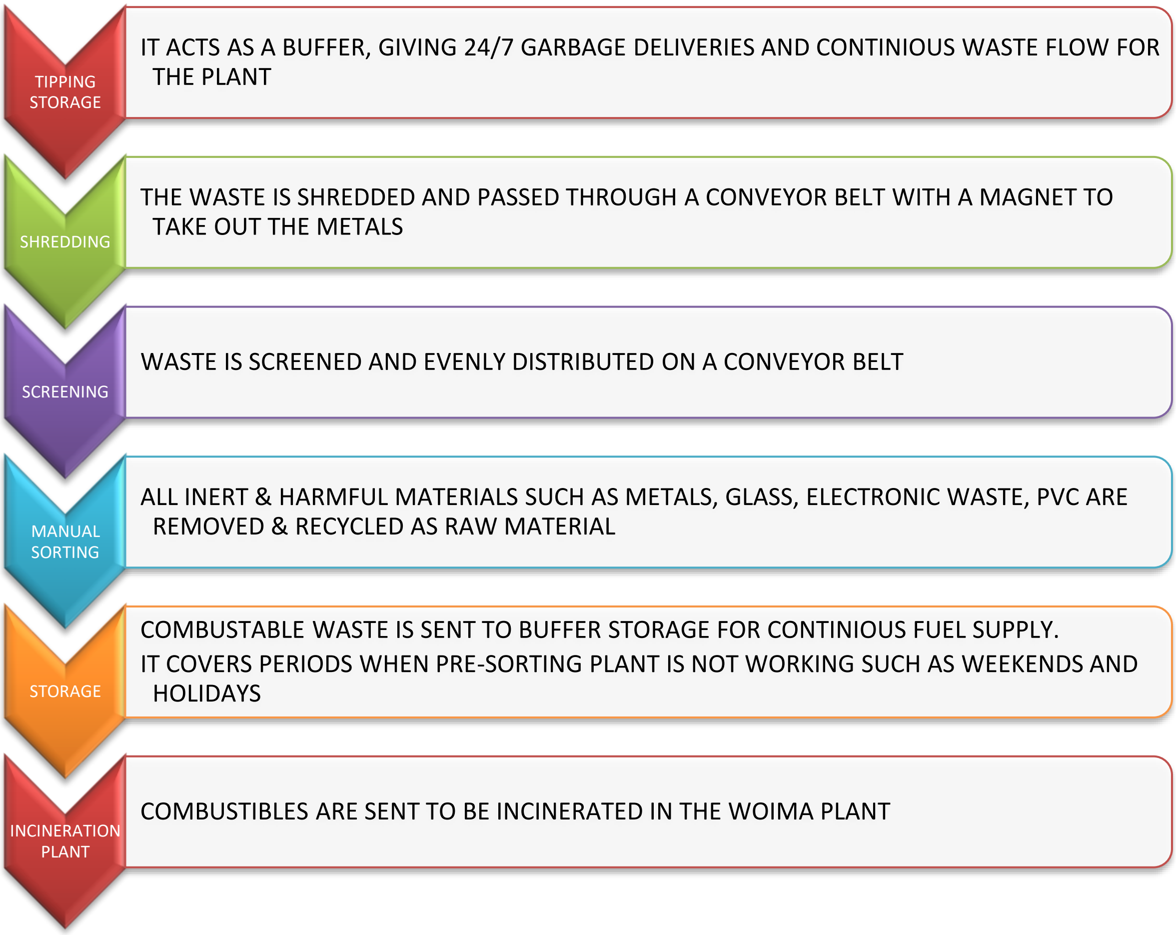

Figure 7. Woima pre-sorting solution

3 COUNTRY OVERVIEW OF PAKISTAN

The PESTEL tool is used to analyze the macro-environment of doing business in a country. The following section will present an overview of the description of PESTEL (P, political; E, economic; S, social; T, technological; E, environmental; L, legal), and how they can affect WtE implementation in Pakistan.

3.1 PESTEL

Political factors affecting the waste management in Lahore are presented in Table 6 below: /14/

Table 6. Political factors

Factor	Description
Government stability	Pakistan´s political stability is weak (average of -2.1 from 1996-2016) which can hinder many of the processes when implementing a WtE project. /World Bank/
Corruption	Ranked 120/180 in the corruption perception index 2019, the level of acceptance of corruption is high in Pakistan. /27/ This can cause problems with costs of a WtE project. It can delay implementation processes.
Local government plan	Local government can provide policies to encourage investments in waste to energy technologies.

Table 6. Political factors

Factor	Description
Government priorities	Lahore does not perform very well in governance features. Inclusivity of users and providers of the waste management system is low in the city, as not all stakeholders are consulted in the decision-making processes. Waste management costs US$20 per tonne of waste, where the main focus is only on waste collection, and the current user fees are much lower than the actual costs. /17/ Non-renewable sources have remained the priority for energy production. According to an economic survey of the Government of Pakistan in 2015, the energy mix in Pakistan primarily depends on extraction of energy from non-renewable sources. /16/ In 2008–2009, the Government of Pakistan paid 9 billion US dollars to import oil to overcome low efficiency thermal plants. This caused a great burden on the country’s economy, followed by environmental pollution. /16/ Renewables are starting to come now into Pakistan. Public health is still the major driver for waste management in Lahore.
Influence of politicians	In Lahore, the private sector participates in the provision of the waste services, but it has been observed that most decisions taken about selection of private contractors are political./17/ Thus, the political influence is high and will affect the implementation decisions of the WtE project.
Bureaucracy	Procedures take time in Pakistan and so delay of permits is a high possibility.

Environmental factors affecting the waste management in Lahore are presented in Table 7 below: /14/

Table 7. Environmental factors

Factors	Description
Environmental guide-lines	Decision making in SWM planning is done by City District Government Lahore (CDGL), LWMC, Environmental Protection Agency (EPA) and other ministries if required. /17/
Environmental targets	The economy's expected long run growth potential of 6.5% also decreased down to 2% due to an energy crisis in the country. At present, Pakistan has adopted the coal fired power plant technique to minimize the energy crisis under China-Pakistan Economic Corridor (CPEC) projects, adding a greater share to the non-renewable energy mix. /16/ Government of Pakistan has set target of generating at least 20% on-grid renewable energy by 2025 & 30% by 2030. /28/
Climate change	According to the **Pakistan Environment Protection Agency** (PakEPA), Pakistan is ranked 135th for global methane emissions on a per capita basis, contributing ~0.8% of the total global GHG budget. /16/ The composting plant project in Lahore was registered as a clean development mechanism (CDM) project by the Board of the United Nations Framework Convention on Climate Change (UNFCCC) in April 2010. /17/

Table 7. Environmental factors

Factors	Description
Geographical landform	Pakistan is an agrarian country and so it has a huge potential for biomass (bioenergy) production. Such as wheat straw, cotton stalks and shells, corn cobs, sugarcane tops and trashes, bagasse, rice husk, animal dung, and poultry manure. These biomass resources are locally available throughout the country and are used inefficiently for heating and cooking purposes. /20/ Pakistan in the 4th largest producer of sugar cane. /20/
Environmental awareness	According to a public survey done in Pakistan in 2014, almost 80% of the people are concerned about the impacts of waste on the environment, however, only 30% were ready to separate their waste for recycling purposes. Only 20% of people said that they were aware of the waste management policies in the city, even though LWMC claims to promote frequently waste management targets and goals in the city. /17/ The estimated amount of methane emission from landfills in Pakistan is 14.18 Gg per year. /16/

Social factors affecting the waste management in Lahore are presented in table 8 below. /14/

Table 8. Social factors

Factors	Description
Demographics	Lahore has a population of about 11 million (total round 212 million). It has a growth rate of around 2.4%, which indicates the population will increase, thus increasing the amount of waste. This increases the need of waste management and waste solutions. Lahore's average generation rate of MSW is about 0.65 kg/capita/day. The daily production of MSW would reach to 7150 tons/day. /16/ Lahore is administratively divided into nine towns, which are further divided into 150 union councils. /17/
Culture	Islam is the dominant religion in Pakistan and so people, customs and traditions are commonly followed around it. Greetings are normally between the members of the same gender. A sense of urgency is not often displayed within business matters. The country has a high-power distance level. It is a collective and masculine society overall. Uncertainty avoidance level and long-term orientation level is low. Pakistan would welcome WtE projects positively.

Table 8. Social factors

Factors	Description
Local/ national events	Religious fest and activities (i.e., Eid's, month of fasting, wedding season) create an increased amount of waste in Pakistan then during any other period within the year. These periods could be considered during WtE technology implementation.
Socio-economic indicators	The dominant waste category in Lahore for all of the socioeconomic levels; biodegradable (56%), nylon plastic bags (11%) and textile (9%). /16/
Resource consumption patters	Pakistan has an average of 7 persons/household, which is high and so the resource consumption is high which means the waste production rate is high as well.
Rural-urban daily migration	In Pakistan, the amount of MSW is steadily increasing due to rapid urbanization, industrialization, technical & economic development, and improved living standards. During the last decade, the population rate in cities has increased from 3.7-7.4%. /17/
Philosophical change	Through increase of education and western culture integration, Pakistan has made changes through time like the rest of the world. There is more awareness now of the waste related issues.
Resistance to change	Pakistan is open-minded and shows a positive attitude towards solutions created for waste problems.

Technological factors affecting the waste management in Lahore are presented in Table 9 below:

Table 5. Technological factors

Factor	Description
Skilled workers; experts	There is a lot of research done on the waste situation and management of Pakistan. Lack of reliable data, poor institutional arrangements, non-compliance of laws, limited resources (finance and equipment), lack of trained manpower are the major constrains for proper management of MSW. Although there is a lack of trained professionals within the waste management sector, with proper training given it should not be a problem. /22/
Application of suitable technology	There is a growing number of private investors. Insufficient collection equipment in Lahore (such as improper segregation, poor collection, and transportation frequency). /16/ Lack of the modern methods of biomass collection and handling like briquetting and palletizing are the wastage of exploitable energy potential. /20/ Inefficient boilers and furnaces. /20/
Facilities availability	Only 55% of villages in Pakistan have a grid connection for electricity. /20/

Table 6. Technological factors

Factor	Description
Rate of technology change	There has been increased digital advancements and improved connectivity infrastructures due to CPEC. Pakistan is a fast adopter of technology and IT usage is high. /25/
R&D activities	In Pakistan there is a lack of locally developed technology. Direct incineration of biomass is done. /20/

Legal factors affecting the waste management in Lahore are presented in Table 10 below: /14/

Table 10. Legal Factors

Factor	Description
Local policy	Policy for alternative and renewable energy 2019 Pakistan. /27/
Relevant SWM/incineration law	In Pakistan there are no specific laws for such projects. Provinces take responsibility for enforcement of the environmental laws, and the task is further delegated to the districts, municipalities, and union councils./17/

Economic factors affecting the waste management in Lahore are presented in Table 11 below: /14/

Table 7. Economic Factors

Factors	Description
Potential income from waste	Tariff of around US cents 10/kWh for waste to energy, which is quite low compared to other countries.
Trade restrictions on waste	None
Availability of funds	The Alternate Renewable Energy Board of Pakistan encourages private sector investment to ease the pressure on public pursue for investments in energy. /28/ Foreign investments are rising in Pakistan and are much needed. 70% foreign investment 30% local
Interest and tax	6 – 10 % interest rate Corporate tax rate is 29%
Economic growth patterns	Pakistan's economic growth is about 5.8% and there has been an increased investor confidence. Pakistan has one of the fastest growing ecommerce markets. /25/
Incentives	The Alternate Renewable Energy Board of Pakistan offers many incentives to the investors. /28/

3.2 Waste Management in Pakistan

The type of waste found and the current waste management situation in Lahore are found in the sections below. The current waste situation in Lahore can be seen in Figure 8.

3.2.1 Waste Characterization in Lahore

Lahore MSW consists of biodegradable, nylon, plastics, PET, textile, paper-card-board, tetra pack, metals, hazardous waste, Elec-electronic, diaper, non-combus-tible, glass and combustibles. /16/

According to Lahore Waste Management Company (LWMC), 'municipal solid waste (MSW) is predominantly household waste (domestic waste) with sometimes the addition of commercial wastes, construction and demolition debris, sanitation residue, and waste from streets collected by a municipality within a given area'/17/

Hospital waste types found in Pakistan include plastic waste, needles (iron), sy-ringes(plastic), glass, cotton/dressings/cloth, cardboard/papers/wrappers, masks/gloves/sheets, machines (hemofilters), pathological waste, pampers and blades/sharps (iron). /9/

3.2.2 Current Waste Management Situation in Lahore

The primary focus in Lahore is on waste collection and transportation. A properly engineered and controlled waste disposal site (landfill) does not exist. There are two types of waste collection methods in Lahore, namely primary collection and secondary collection. In the primary collection, waste is collected door-to-door by either private companies or informal waste collectors. In the secondary collection, waste is collected from communal waste containers placed in various locations throughout the city. Lahore has one official landfill site (Mehmood Boti) and two unofficial landfill sites (Saagian dumpsite & Bagrian/Tiba dumpsite). There is a composting plant near the Mehmood Boti landfill site, which produces around

47,230 tons/year of compost. Thus 8% of the waste produced in Lahore is converted to compost. /17/

In 2011, LWMC became responsible for MSW management in Lahore. LWMC is responsible for waste transportation, collection, disposal, and street sweeping. The company consists of about 58 officials and 10,000 field workers, and it owns around 500 vehicles. In 2012, two private Turkish companies contracted with LWMC; Albayrak and OzPak became part of the waste management in Lahore. The three companies work in phases within Lahore. /17/

There is no formal recycling system in Lahore, although quite a lot of the waste is segregated after waste collection by informal waste pickers, company workers or household residents. Around 27% of the waste is recycled by these unofficial ways. /17/

Currently LWMC is the best manager of waste in Lahore. They are the best-equipped and managed, with top facilities and collection efficiency. The company collects on average around 6500 tons/day of waste with over a 90% collection efficiency. It produces about 500 – 700 tons/day of compost and refuse-derived fuel (RDF). Currently LWMC transports its waste to the Lakhodair sanitary landfill site, as the old Mehmood Boti landfill site was closed. The Lakhodair dumpsite (52 hectares) is Lahore’s first and only sanitary landfill, which started operating in 2016. /16, 26/

Figure 8. Current Waste Situation in Lahore

4 CASE LAHORE

4.1 Research Setting

Three interviews were conducted for this case study (Table 12). The third interview was an indirect interview, where the questionnaire was sent to the interviewees and they sent back their answers through the email. The interviews took place in the city of Lahore, Pakistan. The interviews were held wherever it was most suitable for the interviewees. Appointment dates were fixed by the researcher prior to the meeting and the interview questions were sent beforehand to the interviewees by email.

4.2 Data Collection

As mentioned in Section 1.3 of the thesis, structured and semi-structured interviews were conducted in Lahore. The interviews were conducted in English and Urdu. The summary of the interviewees are presented in Table 12 below.

Table 12. Summary of interviews

Interview	Date of interview & Duration	Name	Position/Responsibility
1	24.12.2019 (3.5 hours)	Dr. Muhammad Rafiq Khan	Senior Researcher/Professor of Environmental studies at Lahore School of Economics
2	25.12.2019 (3 hours)	Muhammad Nasrullah	Process Specialist at Chemitec Consulting Oy, Espoo
3	22.12.2019	-	Employee at Lahore Waste Management Company

4.3 Findings from the Interviews

4.3.1 Key Factors (Barriers) in Developing a Suitable Waste Management System in Pakistan

The findings from the interviews about the key factors in developing a suitable waste management system in Lahore are listed below (Table 13).

Table 8. Factors for Waste Management in Pakistan

	Interview		
Factor	**1**	**2**	**3**
Waste Parameters	The waste is mixed, and Lahore generates about 7000 tons/ day of waste.	The waste in Pakistan is non-sorted and is com-ing from various sources (mixed). The waste quantity is Lahore is an average of 6500 tons/day with a moisture content of 40% – 50%.	LWMC deals with non-sorted waste, with the source of waste coming from municipalities and 5500 tons/day of waste. Waste composition includes combusti-bles (3.8%), paper (2.5%), plastics (0.6%), biodegrada-bles (~64%). The waste has a calorific value of 1.692 Kcal/kg and themois-ture level is 45.9%.

Table 13. Factors for Waste Management in Pakistan

Factor	1	2	3
Tipping/gate fee	The interviewee suggested that there could be a fee of 18 dollars/ton in Lahore.	There is none at the moment, however interviewee suggested that there could be a model such that Pakistan´s government will provide the waste in which case there would be no tipping fee.	None
Local applicable waste collection, management, and incineration legislations	-	The legislations are done mainly in big cities such as Lahore and Karachi. However, they are not taken into consideration by Lahore currently. There is a lot of awareness needed in this area and need of experts to motivate/provide knowledge.	-

Green initiatives	It is all a propaganda in Pakistan; however, the Ministry of Climate Change Lahore is looking into it.	There are no taxes on the import of machinery for such projects for 10 years. There are talks about such initiatives, however Pakistan needs support from outside.	-

4.3.2 Suitability of the WOIMA Technology is Pakistan

The findings from the interviews about the suitability of the WOIMA technology in Pakistan is discussed and the feasibility of the plant (Table 14) is evaluated below.

The factors influencing the implementation of a WtE Project in Lahore were investigated. According to interviewee 2, the government is willing to give land for such a plant if they are convinced. His company is offering a 5MW solution to Pakistan for which around 15 acres (6 hectares) of land would be needed and he thinks it would not be a big problem getting the land. Furthermore, his company would lease the land, which can be a long-term lease of more than 30 years. According to interviewee 3, there is land available at Lakhodair for the plant and his company (LWMC) owns it.

The environmental impact assessment (EIA) process in Pakistan involves identification, screening, scoping, impact prediction and mitigation. According to interviewee 2, an EIA is done for other types of energy plants/projects; however, there is no legislation for waste energy. He suggested that, if they European legislations was adopted in Pakistan that would be perfect for the country. Pakistan needs help from Europe to set the environmental targets. It takes around 3 – 6 months to do the EIA in Pakistan.

To implement a WtE power plant a permission or a license from the government of Pakistan is needed as waste is a provincial matter at the moment, it cannot be done privately. The permits required for building the plant can be obtained from the Energy Department Punjab, NEPRA. According to interviewee 2, it will be easier to obtain the permits for whomever takes the lead in this business. There is no competition on WtE in Pakistan at the moment.

There are some air emission standards for, NOx, SOx, and carbon content (LWMC); however currently there are no protocols by the EPA (environmental protection agency) personnel of Pakistan for controlling them. To set up a power plant in Lahore, one must apply for a power -producing license for the national grid, which can be obtained easily in Pakistan once the techno-economic matters for the project are resolved. In addition, an agreement with the local IPP (independent power producer) must be made in order to produce and sell energy from the WtE power plant.

A grid connection license is required, which can be obtained easily. The main problem in Pakistan is the grid infrastructure - there are line losses. An agreement with the waste collector also needs to be made for the project implementation. If the energy from the plant is sold nationally, the agreement/license will come from National Electric Power Regulatory Authority (NEPRA). The price of electricity sold to the grid is about 7 – 8 cents, however it could rise up to 10 cents if Pakistan's authorities are persuaded.

The project implementation process starts with meeting with the government authority or private investor and presenting them with the solution of this WtE technology. They might ask about the techno-economic aspects of the projects, such as the costs, capacity, output, and type of plant. Then the funding process for the project is implemented.

There are incineration plants in Pakistan, however, they only incinerate hazardous hospital waste and do not produce any energy. Pakistan does not have any priority in waste to energy. As the payback period is long, private investors do not want to invest themselves and instead want the government to take part in it with them. At present, Pakistan is becoming interested and looking for waste solutions from outside. Pakistan is looking for a PPP model and expecting funding from outside for such projects.

Table 14. Feasibility of WOIMA plant according to findings

Factor	**WOIMA technology**	**Findings**	**Feasible**
Waste Capacity	150-200 tons/day	5500 – 7000 tons/day	Yes
Types of waste	1. Municipal solid waste (MSW) 2. Refined waste fuels (RDF, REF, SRF) 3. Industrial, commercial, and institutional waste 4. Construction and demolition waste 5. Agricultural waste 6. Different biomasses	Mixed, non-sorted, RDF	Yes
Moisture content	up to 55%	40 – 50%	Yes
Calorific value	7 – 16 MJ/kg	7.08MJ/kg (1.692kcal/kg)	Yes
Area	4 lines = 9000 m^2 / 13600m^2 (0.9 hectares)	6+ hectares	Yes
Energy production	4 incineration lines = 11.4MW	-	-

4.4 Analysis of the Interviews

The following section presents the results and the analysis of the interviews.

1. Waste data and characteristics

From the interviews, it was found that the waste quality and quantity meet the WOIMA WtE technology requirements. This means Lahore has met the most important challenge of implementing a WtE plant. There is no sorting of MSW happening in the city for either households or commerce. There is no separate collection of recyclables and organics, either. About 64% of the waste sent to disposal is compostable. There are no seasonal waste variations/ transboundary waste flows that could affect future waste projections; however, the waste production is increasing with time which raises the need for such WtE solutions.

2. Infrastructure

A systematic waste collection and transportation system exists, run by the Lahore Waste Management Company. A controlled landfill is also available for safe disposal of WtE residues, although the matter was not exactly clear from the interviews. This means Lahore's infrastructure supports WOIMA plant implementation.

3. Environmental aspects

The emission standards for WtE follow the international standards, however they are not considered important in Lahore. There is capacity to monitor emissions regularly with the right technical planning. However, there are no compensatory strategies available currently to mitigate environmental impacts, although from the overall findings it can be said that they are being and can be implemented with the right understanding. Some pollution from the waste and huge piles of waste at the landfill sites can be an occupational health risk for the workers but through clean initiatives and emission controls taken more seriously in Lahore, these risks can be mitigated. Pakistan is mainly focused on the risks of air pollution caused by the health hazardous gases and consequent respiratory diseases and others such as the health of the workforce engaged in carrying out the processes involved in waste management.

4. Economic aspects of Lahore

The energy that is produced from the WOIMA plant can be accessible to local users and become available for sale in the market. There is also an available market in Pakistan for WtE residues, the ash produced can be used for making bricks for construction. Most of the construction building in Pakistan use bricks. Currently, no long-term financial sources have been secured for this project as it is a case study however, the possibilities seem positive from the interviews. Access to foreign currency is also possible.

5. Legal aspects

A comprehensive legal framework and decommission regulations do not exist currently for WtE technologies in Pakistan. WOIMA Corporation can provide help with these aspects in order to implement a WtE technology in Lahore.

6. Social aspects

Working conditions of informal recyclers can be improved through the implementation of this project. There are currently no compensatory strategies available to mitigate social impacts by Pakistan but WOIMA can provide them.

7. Risk assessment

Pakistan is a natural disaster-prone country due to its geographical location where heavy monsoon, flooding, earthquakes, droughts, landslides, and storms have occurred in the past/18/. It is a developing country with inadequate sources at times to have recovered from the severe catastrophes. Future prospects of natural risks can be severe. The severity depends on the location of the plant. Pakistan lies on such a vast area that the severity varies. These risks can be simply avoided by making the right choice of site for the WtE plant. Lahore comes under the area of low vulnerability to disaster and thus, the plant is located in a safe area. Risks can be avoided through effective risk mitigation plan for the power plant. Pakistan has also initiated multi hazard and risk assessment studies in the province of Punjab, where Lahore lies. Regarding the effects of natural disasters on waste to energy plants, we may consider chain line for waste to energy plant in Pakistan. For instance, these type of disasters may affect the activities related with waste collection, waste logistics, break of infrastructure (for example roads and electricity connection) plant may be broken/flooded and some other related damages.

8. Alternatives

There could be alternative WtE technologies suited for Pakistan, a biogas plant or other technologies that produce bioenergy. They can be alternatives as organic waste levels are high. However, the WOIMA plant meets with the local conditions and waste parameters of Pakistan and thus is a suited option.

5 CONCLUSION AND DISCUSSION

The growing waste problems of Pakistan are in need for proper waste solutions. However, practical implementation has yet to be done to control the growing waste amounts. This thesis aims to highlight these problems to be able to create a proper waste management system and give practical steps to implement a WtE technology in Lahore, Pakistan. In this thesis, a case study was done of Lahore's current waste management system and the implementation factors of a Waste to Energy technology. The different types of wastes and waste to energy technologies were studied. The aspects and processes in order to implement a WtE technology were addressed. A PESTEL analysis of Lahore was conducted and the waste situation of Lahore was studied.

The findings of the study show that the key barriers hindering the implementation of a suitable waste management system in Lahore are moisture content of the waste, tipping fees and the waste legislations. For example, the moisture content of Lahore was around 40 – 55%, which can affect the energy levels obtained from the WtE plant. From the economical perspective, the tipping fee will be a critical factor in attracting investors to participate in WtE projects in Pakistan. Currently, there are no legislations pertaining waste, which could affect the implementation of a WtE solution. In addition, the study found that the WOIMA waste technology is suitable for Lahore's environment.

From a practical point of view, the information provided in this thesis can be used as a guideline in determining the implementation of waste management systems and selection of WtE technology.

The limitation of the research is related to time and cost because the researcher had limited time in Pakistan. This affected the possibility of gathering additional information. The results cannot be generalized. In further studies, the financial aspects of implementing this project should be considered to make it commercially viable.

REFERENCES

/1/ Waste to energy considerations for informed decision-making. United Nations Environmental Program Report.

/2/ Sarma, P., & Mehta D. 2015. A comprehensive study of waste management system in Indian cities: Policies ad strategies. Simon Fraser University

/3/ Khan I., & Kabir Z. 2019. Waste-to-energy generation technologies and the developing economies: A multi-criteria analysis for sustainability assessment. Accessed 29.1.2020. Doi: 1-s2.0-S096014811932004X-main.

/4/ Gumisiriza, R., Hawumba, F.J., Okure, M., & Hensel, O. 2017. Biomass waste-to-energy valorisation technologies: a review case for banana processing in Uganda. Accessed 1.2.2020. Doi: 10.1186/s13068-016-0689-5. School of Biosciences, Makerere University.

/5/ Moya D., Aldás C., López G., Kaparaju P. 2017. Municipal solid waste as a valuable renewable energy source: a worldwide opportunity of energy recovery by using Waste-to-Energy Technologies. Accessed 3.2.2020 Doi: 1-s2.0-S187661021734763X-main. Elsevier Ltd.

/6/ Kumar A., & Samadder S.R. 2017. A review on technological options of waste to energy for effective management of municipal solid waste. Accessed 3.2.2020. Doi: 1-s2.0-S0956053X17306268-main.

/7/ A comprehensive analysis of food waste derived liquefaction bio-oil properties for industrial application. Doi: 1-s2.0-S0306261918319032-main.

/8/ Rasheed S., Iqbal S., Baig A.L., & Mufti K. 2005. Hospital waste management in the teaching hospitals of Karachi.

/9/ Munir S., Batool A. S., & Chaudhry M. N. Characterization of hospital waste in Lahore, Pakistan. 2014. Accessed: 7.2.2020. Doi: 10.3760/cma.j.issn.0366-6999.20132088.

/10/ Baird J., & Amasuomo E. 2016. The Concept of Waste and Waste Management. Accessed: 9.2.2020. Doi:10.5539/jms.v6n4p88.

/11/ Alemayehu E. 2004. Solid and Liquid waste management for health extension workers. Lecture Notes. Jimma University.

/12/ Ferronato N., & Torretta V. 2019. Waste Mismanagement in Developing Countries: A Review of Global Issues. Accessed: 6.3.2020. Doi: ijerph-16-01060.

/13/ Municipal solid waste incineration. World bank technical guidance report. The world Bank Washington D.C.

/14/ Mukhtar M. E., Williams D. I., & Shaw J. P. 2018. Visibility of fundamental solid waste management factors in developing countries. Accessed: 7.4.2020. Doi: 10.26403/detritus/2018.16.

/15/ Huopainen P. 2014. Emotional intelligence and multicultural project leadership in Finnish Chinese MNC context. Accessed: 11.3.2020. Lappeenranta University of Technology.

/16/ Azam M., Jahromy S. S., Raza W., Raza N., Lee S. S., Kim K., & Winter F. 2020. Status, characterization, and potential utilization of municipal solid waste as renewable energy source: Lahore case study in Pakistan. Accessed: 18.4.2020. Doi: 1-s2.0-S0160412019322986-main.

/17/ Masood M., Barlow Y. C., & Wilson C. D. 2014. An assessment of the current municipal solid waste management system in Lahore, Pakistan. Accessed: 18.4.2020. Doi: 10.1177/0734242X14545373.

/18/ UN office of Disaster Risk Reduction. 2019. Disaster risk reduction in Pakistan status report.

/19/ Shah A. Z. S., Nawaz Z., Nawaz S., Carder G., Ali M., Soomro N., & Compston C. P. 2019. The role and welfare of cart donkeys used in waste management in Karachi, Pakistan. Doi: 10.3390/ani9040159

/20/ Kamran M., Fazal R., & Mudassar M. 2019. Towards empowerment of the renewable energy sector in Pakistan for sustainable energy evolution: SWOT analysis.

/21/ Lee Y. Z., Sankaran R., Chew W.K., Tan H.C., Krishnamoorthy R., Chu D., & Show P. 2019. Waste to bioenergy: a review on the recent conversion technologies. Accessed: 11.5.2020. Doi: s42500-019-0004-7.

/22/ Ilyas H., Ilyas S., Ahmad R.S.,& Ch N.M. 2017. Waste Generation Rate and Composition Analysis of Solid Waste in Gujranwala City Pakistan. Doi: 10.4172/2252-5211.1000297.

/23/ Sintef. Accessed 05.02.2020. https://blog.sintef.com/sintefenergy/what-is-hydrothermal-liquefaction-and-why-is-it-interesting/

/24/Woima Corporation. Accessed 07.04.2020. https://woimacorporation.com/technical-solution/

/25/World Economic Forum. Accessed 17.04.2020. https://www.weforum.org/agenda/2018/11/pakistan-s-digital-revolution-is-happening-faster-than-you-think/

/26/ Daily Times. Accessed 18.04.2020. https://dailytimes.com.pk/559495/lahores-only-landfill-site-about-to-reach-its-capacity/

/27/Transparency International. Accessed 25.04.2020. https://www.transparency.org/country/PAK

/28/Government of Pakistan. Power Policy. Accessed 17.04.2020. http://www.aedb.org/images/ARE_Policy_2019_AEDB.pdf

/29/ Qualitative Research. Accessed 28.03.2020. https://en.wikipedia.org/wiki/Qualitative_research

/30/Case Study. Robson 1993. Accessed 28.04.2020. https://www.youtube.com/watch?v=gQfoq7c4UE4&feature=emb_logo

/31/ Mapping Research Method. University of Jyväskylä. Accessed 12.04.2020. https://koppa.jyu.fi/avoimet/hum/menetelmapolkuja/en

/32/ EU Waste Definition. Accessed 16.04.2020. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008L0098&from=EN

APPENDIX 1

Interview Questions

1. What are the parameters of the available waste?

- Sorted/non-sorted/RDF, SRF
- Source of waste (municipal, industrial, commercial, institutional, etc.)
- Composition % (organic, plastics, wood-based, glass, metals, other)
- Quantity (tons/day)
- Calorific value (MJ/kg)
- Moisture %

2. Does a gate fee/tipping fee for landfilling waste exist? How much is it (per ton)?

3. What is the availability of a suitable plot/ land for the power plant? What is the status of land in Pakistan for such project and the zoning situation with land?

4. Do you own the land or lease it? What is the lease rate? (company)

5. What is the Environmental Impact Assessment (EIA) process like for such projects? Have you prepared an EIA?

6. What is the estimated cost and time frame of the EIA?

7. What are the authorities involved and their role in a W2E power plant?

8. What the required permits for building a waste-to-energy power plant? (environmental permit, building permit, water permit, etc.)

9. What is the local applicable waste collection, management and incineration legislations?

10. What type of air emissions standards are there governing waste incineration in Pakistan?

11. Does a protocol for controlling air emissions by EPA personnel or accredited consultants exist and if so, what are the annual costs?

12. Does the plant owner need to apply for a power producing license from National Energy Regulator? How long does the licensing process take?

13. Is a grid connection license required? How is that obtained?

14. Is there a grid connection fee? How much is it?

15. Is an agreement with the local IPP (independent power producer) Board or similar for the right to produce and sell energy commodities by W2E power plant required?

16. Any other licenses or applicable fees required for such project?

17. Please list the project development and license application process

18. What are the local import taxes applicable for W2E power plant?

19. Have you obtained any legal advice on building a W2E power plant, can we please review it?

20. What is the price of electricity sold to the grid?

21. Are there any green initiatives in Pakistan